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WINTER CONSTRUCTION

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This is one of the series of bulletins on better building practice prepared by the Division of Building Research, National Research Council, as part of its service to the construction industry of Canada; it deals with

WINTER CONSTRUCTION

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PURPOSE OF THIS BOOKLET

Winter construction has come to be a well-accepted feature of the construction industry in Canada. Many great engineering projects such as the immense Shipshaw power scheme have been carried out with much of the work upon them performed during severe winter periods. The success of Canadian constructors in carrying out major building operations throughout Canadian winters has won for them an enviable reputation.

Despite this, it is not generally appreciated that even the smallest construction projects, including house building, can be carried out just as satisfactorily during winter periods, with little extra cost involved but with some advantages over summer construction – provided that all winter work is properly planned.

So much is to be gained by an increase in the volume of winter construction in Canada, particularly in the reduction of seasonal unemployment which will result, that the Government of Canada has officially endorsed efforts toward the extension of winter building work. This booklet is a contribution from the National Research Council Division of Building Research towards this goal.

It is intended to show how proper management can be applied to all normal building operations with a view to making them easy to perform during winter weather. The booklet deals with each major building operation. For convenience, many common features are repeated under the respective headings in order to make each section complete in itself.

This booklet is merely an introduction to a vast subject, but it is hoped that it will make clear that Canada's reputation for good building during the winter can apply just as well to the small job as to the major construction enterprise, provided that proper advance planning is done. The booklet starts with a brief section on planning, since planning alone holds the key to real success in winter construction.

PLANNING

Construction men agree that the additional costs of winter construction are negligible when the job is closed in before severe weather arrives. In fact, there are many cases where lower costs result owing to such factors as availability of labour, building materials and equipment and easy access to the building site.

A study of such cases shows, however, that very careful and detailed planning came first. The object of this planning is to schedule and time each phase of the job so that the least possible inconvenience is suffered due to the weather. The ideal situation results when the building is closed in before winter comes. When this is not possible then proper planning will ensure that provision has been made to overcome the problems associated with winter construction. It must be pointed out that many of these problems are no more severe than those to be found on construction jobs at other times of the year.

Planning winter building operations requires a knowledge of local weather conditions. Builders who have been building in the same area for a number of years can plan their winter operations on the basis of their own experience. Others lacking this local information can obtain it from the nearest meteorological office.

Before winter operations begin, and particularly before the first period of heavy frost or heavy snowfall, provision should be made for access roads, drainage, services, land clearing, lot layouts, and excavations. Some of these jobs can be difficult or impossible once winter has set in.

In addition, it is well to make pre-winter arrangements for water supply for construction purposes, temporary power, space and shelter for the storage of building materials, shelter for the workmen, and protection and maintenance of tools and equipment.

Roads and ditches should be put in early so that equipment and materials may be easily moved to and from the site. Side

clearances should be provided for snow removal. Roads are much easier to build before the ground freezes and before fall rains or early snowfalls. Good drainage is necessary to maintain a road usable and trouble-free for several months. Besides access roads from main roads to subdivisions, it is important that driveways be roughed in to carry trucking loads. Suitable culverts should be provided for driveways to carry loads and to provide as much drainage as possible away from the building lots.

Availability of building materials and equipment on short notice is one of the advantages of building in winter. Because of this it is important that roads be provided and maintained so that materials can be ordered as needed. This reduces the amount of space and shelter that would otherwise have to be provided for storage on the site. Good roads to the site should be maintained to facilitate the movement of fire fighting trucks and equipment and to remove combustible materials quickly and economically from the path of a fire.

Municipal services such as electric power, water, and sewers should be arranged for well in advance of the construction starting time so that there will be no holdups due to bad weather or trenching in frozen ground. Where storm sewers are to be provided, the site should be drained before cold weather sets in. It is best to install septic tanks at the time of excavating for the foundation. A septic tank can be put in place in winter provided the ground is covered by snow, brush or straw to prevent frost penetration and to make cold weather excavation possible.

Disposal beds should be backfilled and covered with straw or snow to prevent freezing and heaving of the tile. Keep workmen and vehicles away from the disposal bed area as uncompacted snow cover will reduce frost penetration. If cold weather is expected before there is snow cover on the ground, the disposal area should be covered with a foot or two of straw until after the septic tank system has been in operation for several weeks.

Lot layout, surveying, excavation, staking and the establishment of elevations can best be done before the ground freezes or before much snow has fallen. Land clearing and rough grading can normally best be done before snow has covered the site.

The items cited above fall into the category of planning the winter job. They are dealt with more easily before freeze-up or snowfall. This does not mean that they cannot be done in winter – they can, but with difficulty.

SITE ORGANIZATION

Water Supply for Construction Purposes

In winter, precautions must be taken against freezing of water pipes to ensure an adequate water supply for on-site concrete, masonry, and plaster work. In addition, water should be available for fire fighting purposes. Water pipes can be protected against freezing by insulating or heating.

Where water under pressure is available, a frost well can be put down to the depth of the water main. The bottom of the well must be equipped to drain to a sewer or porous ground so that the service pipe can be readily emptied at night. Where necessary the valves and couplings can be protected by a layer of straw. The well should be covered to exclude snow. Rubber or plastic hoses are often used as temporary service lines. These hoses should be emptied when not in use and stored under cover. Pipes should be supported in such a way that no water can remain in them when they are drained.

Insulation for temporary service pipes can be provided by placing the pipe in a trench and backfilling before freeze-up. If trenching is not practicable then pipes can be laid in boxes filled with shavings or sawdust. Four to 6 inches of dry insulation will prevent freezing of still water in pipes for 24 hours on most construction sites. A small amount of insulation may be enough if water is being run continually through the pipe but the pipe must be drained after working hours if the water is shut off.

Electrical heating of pipes is effected by passing a low-tension current, supplied from the power lines through a transformer, through the pipe proper, or through an insulated cable passing through the pipe. There are "wrap-around" cables available that operate on normal supply voltages and these, together with some insulation, will provide enough protection for most winter jobs.

Storage and Protection of Materials on the Site

Millwork, finish flooring, asphalt shingles and cement should be stored in a warm dry location. Lumber, plywood, insulating sheathing, gypsum board, masonry units and masonry materials must be kept dry. Certain materials such as reinforcing steel and cast-iron pipes suffer no direct damage through exposure for a few months; nevertheless, work will be slowed down if they are encrusted with snow and ice. Materials not requiring coverings should at least be stored off the ground on platforms or skids to prevent their freezing to the ground.

The Fire Problem

Make sure that salamanders and other temporary heating equipment do not set fire to formwork and tarpaulins. Fires may occur from welding and cutting operations but most of the fires in formwork have started in tarpaulins from portable heaters.

A flameproofing liquid for treating tarpaulins in the field was developed during the war for the armed forces. A specification for the liquid and its application is available (Canadian Government Specifications Board Specification 4-GP-56).

Salamanders should be placed on the ground or other incombustible base. If placed on wooden floors, salamanders must be insulated by at least 3 inches of incombustible material covered by sheet metal and extending two feet beyond all sides. There should be a clear distance of at least 30 inches in a horizontal direction from all wood construction and a clear distance of 6 feet above all salamanders.

Do not throw chunks of asphalt that are covered with ice or snow into a heating kettle. The conversion of the ice and snow into steam in the hot asphalt will cause spattering and may also cause the kettle to overflow and start a fire. Never heat asphalt cement directly over a fire; put unopened cans in hot water to warm.

Fire hoses should be kept close to all formwork and buildings when heaters are being used on the job. If there is danger of freezing, the fire main should be kept drained and controlled by a valve protected from freezing but easily accessible. Hand extinguishers are a valuable supplement to a supply of water. These should be checked periodically to determine if they are fully charged and in good working order.

EXCAVATIONS AND FOUNDATIONS

Excavating

Modern excavating machinery can readily operate in ground frozen to a depth of 1 foot. Earthwork will usually cost less, however, when it is done before or between frost periods. For a well-planned winter job it is possible that all excavating and trenching can be done before cold weather.

Earth that is to be excavated after winter sets in can be covered with brush or straw to reduce frost penetration. If heavy snows precede periods of very low temperatures, then this snow cover should be left undisturbed to provide a blanket of insulation over the area to be excavated later. Rock excavations present no particularly difficult problems at temperatures above 0°F.

Excavating is sometimes easier in winter. Drainage and well-point work is often reduced or eliminated during cold weather. Shoring, cribbing, and piling may also be reduced if the ground is frozen so as to maintain a certain stability with slopes and vertical cuts.

Frost protection inside the excavation is usually necessary. Straw should be placed in the bottom of the excavation and

up the sides for a few feet. This will reduce frost penetration and make it possible to place footings on an unfrozen base. The straw is removed immediately before placing the concrete for the footings and replaced as soon as the concrete is placed to ensure proper curing of the concrete. On a rock base, heating with steam before the footing concrete is placed will provide better curing conditions for the concrete.

Sides of excavations and embankments having a south or southwest exposure are subject to cycles of freezing and thawing with consequent sloughing and caving in. Straw placed against these sides and covered with tarpaulins will usually stop this action, and make work on the footings and foundation walls easier.

Thawing operations may be necessary where excavations must be made at the height of the cold weather.

Where frost has penetrated deep into the soil, fires can be used to thaw the ground. For sewers and water-mains this may be done by spreading approximately 1 foot of hay or straw covered with 3 inches of slack coal. When a good tight job of spreading the coal over the straw is accomplished, the ground will be thawed to a depth of as much as 3 feet by one burn. Wood scraps and petroleum products can also be set afire. Flame throwers are beginning to make an appearance for thawing small sections at a time.

Steam is sometimes used by one of the following methods:

(1) thin coils laid on the frozen surface;

(2) steam jets keeping water warm in a pit;

(3) steam points melting their way into the frost crust.

The last-mentioned method has proved to be the most effective means of thawing with steam.

Foundations

Concreting against frozen ground is poor practice. Excavations should be made just before placing concrete, or so protected that the bottom and sides do not freeze. The same applies for trenches for sewers and drains.

One of the most common and serious types of frost damage is by frost heaving of foundations. It is absolutely essential to prevent freezing of the ground below the foundation. If a basement is left open or unheated, insulation must be provided over the entire foundation, and on concrete floors. A twenty-inch layer of straw or hay will usually provide the required amount of protection for short periods.

Forms for foundations should not be placed on ice or snow. All ice or snow on the inside surfaces of forms and between forms should be removed before concrete is placed. This can readily be done by steaming. The base must be thawed before footings are placed and kept that way thereafter. Steel reinforcement and construction joints must be free of snow and ice and preferably warm.

Masonry units for foundations should be thoroughly cured. Those having a moisture content greater than 20 per cent should not be used. Blocks should not be used that have ice on them. Dry blocks permit mortar to set faster. Blocks should be warmed when temperatures fall below 40°F. These precautionary measures lessen the chances of damage by frost.

Mortar for block foundations should be prepared from warm aggregate and the mixing water must be heated when the temperature is below 40°F. Mortar should be prepared in small batches and kept warm until it is used. Mortar and masonry materials should be maintained at a temperature of not less than 40°F during laying and for at least 48 hours after laying.

Drain tile may be placed around the footings and covered with crushed rock or other granular material. Straw or hay should then be placed on top of this material to prevent frost heaving and freezing of the tile and footings. Proper outlets for the tile must be provided to take care of early spring runoff. No backfilling should be done until spring unless unfrozen material is used. This should be placed in layers of 6 inches to one foot and compacted to prevent future settlement and subsequent ponding of water near the foundation wall.

A good general rule to follow for excavation and foundation work is to get all excavating done before Christmas and leave the backfilling until spring.

CONCRETE

Winter concreting work requires that one basic law be observed:

"Fresh concrete must not be allowed to freeze before it has hardened sufficiently to prevent its deterioration."

The curing rate of concrete varies with temperature. It is slower in cold weather and almost stops at a point slightly above 32°F. Then, if freezing does *not* occur, curing will continue as soon as the temperature rises.

Good concrete can be obtained in cold weather if heating the materials and protecting the fresh concrete is properly done. Careful supervision is necessary to ensure this.

Lack of protection against early frost may result in immediate destruction or permanent weakening of the concrete. It is therefore apparent that protection against low temperatures and proper curing conditions are important factors on all concrete work in cold weather.

Winter Concreting Methods must:

(1) protect fresh concrete from freezing and then thawing;
(2) allow the concrete to gain strength early, so that forms may be removed and loads applied to the structure;
(3) maintain proper curing conditions;
(4) limit sudden temperature changes before the concrete has developed sufficient strength to resist temperature stresses;
(5) obtain as economic a winter concrete job as possible.

Aggregates must not contain porous limestone which may cause disintegration from frost action. They must not contain clay as clay often contains materials that delay hardening. Porous stone is always undesirable in concrete. Freezing of water in the pores can cause serious cracking and "popouts" of fresh concrete during construction as well as later on, when the concrete has hardened and is exposed to freezing and

thawing. Stone material that is not at least 2½ times as heavy as water, for the same volume, is liable to damage by freezing.

Heating the Mix

For winter concreting, usually only the sand and water need be heated. In late fall, with temperatures slightly below freezing, only the water is heated. Later, as the weather becomes colder and stockpiles freeze, heat is also applied to the sand. Heating of the concrete mix is most conveniently done by heating of the mixing water. At the time of mixing the temperature of the water should be about 140°F. Frozen lumps of aggregate are to be thawed before mixing.

Water tanks, mixers, and wheelbarrows may become cold overnight. In the morning, the temperature of the first few mixes will, therefore, be too low unless the mixer is kept running for a while with hot water. This water from the mixer can then be emptied into the barrows.

Sometimes there is enough initial heat and heat of hydration to prevent freezing. This would be limited to periods when the air temperatures are within a few degrees of freezing. If no protection is provided, newly placed concrete is subject to damage during any sudden drop in temperature. The use of "hot" concrete is apt to lead to excessive cracking on cooling, decreases workability, and increases the possibility of flash set.

The table below indicates, for various outside temperatures, the requirements for heating of aggregate and water and also the recommended temperature of the concrete in the mixer.

Air Temperatures	Water	Aggregates		Concrete Temp. at mixer
		Sand	Coarse	
Above 30°F.	Heated	–	–	50 to 80°F.
30 to 0°F.	"	Heated	–	50 to 90°F.
Below 0°F.	"	"	Heated	50 to 90°F.

Heating of mixing water should be so controlled that there are no temperature variations from batch to batch. When water or aggregates are heated, the cement should be added to the mix last to avoid flash set.

Aggregates should be heated in such a manner that frozen lumps, ice, and snow are eliminated and over-heating or excessive drying is avoided. At no point should the aggregate temperatures exceed 140°F. Steam coils are recommended for heating aggregates.

Placing the Concrete

The temperature of the concrete when placed should be between 50°F. and 80°F. This applies winter or summer. There is nothing to be gained and damage can result if concrete is placed at too high a temperature.

Before concrete is placed, all ice, snow and frost should be removed from forms, reinforcement and other contact surfaces. The temperature of surfaces in contact with the concrete should be above 32°F. No concrete should be placed on a frozen subgrade or on one that contains frozen materials. Concrete must not be placed over ice or snow.

Curing Temperatures

Insulation may be used to maintain proper curing temperatures for limited periods. It should be applied not later than one-half hour after placing the concrete. The loss of heat in the period from mixing to protection is estimated at 15 per cent per hour of the temperature difference between concrete and the surrounding air. If insulation by itself will not prevent freezing, then other coverings, together with an addition of heat, will be necessary.

In Western Canada boards about 18 inches on centres are often tacked onto the back of the studs of the formwork. Straw or hay is then stuffed between the studs as insulation. Where there is little or no wind this method will protect concrete at temperatures down to 10°F. above zero without additional heat.

Fresh concrete will not stand freezing. When it freezes the water it contains will turn into ice, and expand. This will split the concrete, making it porous and weak. At a certain stage of the curing, as given in the table below, the strength of the concrete is sufficient to resist these pressures.

TABLE OF CURING TEMPERATURES AND TIME REQUIRED

Type of Cement	Temperature Maintained	Length of Time
Normal	50°F. 70°F. and 40° F. for the next	7 days 3 days 4 days
High early strength	50°F. 70°F.	3 days 2 days

Surface temperatures of hardened concrete should not be permitted to exceed 80°F. at any time during the curing period.

Excessive temperature changes or differences in temperature within concrete promote cracking and have a harmful effect on the strength and durability of the structure. These effects become important at the time of form removal and when protection against low temperatures has ceased. At such times the surfaces of the concrete may be rapidly chilled and cracking may result.

Temperatures of protected concrete should be reduced at a rate no greater than 10°F. in 24 hours until that of the surrounding air temperature is reached. A protection period during which heat and moisture are provided should not be less than 72 hours. Steam is ideal for curing concrete as both the required temperatures and moisture are available from the same source.

The Use of Calcium Chloride

Calcium chloride should not be used as a substitute for proper curing and frost protection. The use of calcium chloride, sodium chloride, and other soluble materials for the purpose

of preventing freezing solely by lowering the freezing point of the mixing water should not be permitted. The anti-freezing properties of calcium chloride are small, having the effect of lowering the freezing point by only 2 or 3 degrees. The chief reason for using calcium chloride in any season is to decrease the time required for the concrete to harden. Accelerated hardening is accompanied by an increase in the rate at which heat is released by the chemical reactions that are taking place. In cold weather calcium chloride is used to shorten the period during which protection must be provided. The increase in the rate at which heat is given off also provides additional protection to the concrete.

Calcium chloride must not be used indiscriminately or in excessive amounts. There is some evidence that too much calcium chloride may reduce the durability of concrete, intensify the destructive reaction between the alkalies in portland cement and certain susceptible aggregates, and promote the corrosion of metal reinforcement or ducts imbedded in the concrete. It is generally agreed that calcium chloride should not be used in amounts in excess of 2 per cent by weight of portland cement.

Effects of Frost on Concrete:

(1) When the mixing water freezes, the hydration of the cement stops and only begins again on thawing;

(2) Expansion of water on turning to ice has a disruptive effect upon fresh concrete;

(3) Even when not actually freezing, the rate of hardening of concrete in cold weather is much less than at normal temperatures.

There are several conditions which can cause frost damage:

(1) Low strength concrete;

(2) Highly porous concrete;

(3) High initial moisture content;

(4) Access to unfrozen water on the side remote from freezing. (This water may be either inside or outside

the concrete and acts as a reservoir for the growth of ice crystals near the cold or exposed face of the concrete.);

(5) Temperatures below 32°F. in the concrete.

Admixtures rarely improve the frost resistance of concrete that is, in itself, highly durable. In low-grade concrete or in very severe conditions, an admixture may prove useful. Admixtures should only be introduced to the concrete mix by those familiar with their properties and use.

The question is often asked, "Can concrete frozen overnight, be restored by proper treatment the next day?" If it has frozen but once, and is kept wet and warm at the same time, it may be brought to proper strength provided no ice crystals have formed. There is always the danger, however, that such concrete has been permanently damaged.

Form Removal

TABLE OF SUGGESTED TIME PERIODS FOR FORM REMOVAL

Stripping Forms from	Time in Days for Concrete Temperatures and Types of Cement Used			
	Ordinary Portland		Rapid Hardening	
	32°	60°	32°	60°
Walls	8	3	5	2
Beams spanning less than 10 feet	20	7	8	3
Beams spanning more than 10 feet	31	11	11	4

Note: Nonsupporting column forms can be removed after a hydration period equal to 50 per cent of that for a beam, the span of which is equal to the height of the column.

Laying Precautions

Block and brick must never be laid on a snow- or ice-covered base or bed. If this is done there will be movement when the base thaws and there will be no bond between the mortar bed and the base.

Some bricks absorb much water and if laid up in a saturated condition are liable to disintegrate on freezing. Sand-lime and clinker-concrete bricks with low absorption draw very little water from the mortar. A wet mortar used with such units may freeze and disintegrate.

Bricks must be supplied in a dry condition. Wet bricks will freeze together and hamper the work. They will "float" in the mortar and the bond strength will be greatly reduced. The bricks must, therefore, be protected, not only against frost, but against rain, snow, and moisture.

Sudden cooling of warm mortar in contact with cold units must be prevented. It is recommended that masonry units be heated when the outside temperature is below 40°F.

Bricks with rates of absorption above 20 grams per minute should be sprinkled with warm water just before laying. Those with lower rates of absorption can be laid dry. Bricks should be heated when the temperature is below 40°F. One method is to keep an ample supply of brick behind a heated enclosure where the work is going on.

The chief requirement for brickwork is to prevent the mortar and/or brick from becoming saturated and then freezing. Ice formation may cause mortar to crumble and joints to expand. In winter, bricks should not be dipped in water before laying.

Mortar Heating

Mortar must be properly prepared and heated in cold weather. The mixing water and sand should not be heated to more than 150°F. It is important that the sand be heated uniformly. Scorched sand should never be used in mortar. To

prevent this it should be heated slowly and evenly. This can be done by piling sand around an old metal smoke stack or a drum, laid horizontally, in which a slow fire is built or through which steam pipes may be run.

In freezing weather, both water and sand should be heated. The temperature of the mortar when used, should not exceed 120°F. or be lower than 70°F.

Anti-freezing compounds should not be used to lower the freezing point of the mortar. The accelerating effect of calcium chloride is reduced when lime is used in the mortar since the salt acts only on the cement.

Mortar Mixes

(1) Under normal weather conditions, mortar for work above grade should be one of the weaker types. A mix of 1:2:8 or 9 (cement:lime putty:sand) is generally suitable;

(2) Under cold weather or other severe conditions a mortar mix of 1:1:5 or 6 is suggested as being more suitable;

(3) Mixes stronger than 1:1:6 in the order of 1:3 (cement: sand) are only recommended where a dense, strong mortar is essential such as in cases where engineering bricks are used or for masonry construction below grade.

Note: Where mortar stronger than 1:1:6 is used, the use of units of high-drying shrinkage (some concrete blocks or concrete bricks and some sand-lime bricks) should be avoided.

Masonry Protection

Tarpaulins over masonry laid up with warm mortar may be sufficient when temperatures are above 25°F. and rising. In severe weather, enclosures with artificial heat by salamanders or other means are recommended.

Walls should not be baked on one side with no protection on the other. Enclosures should allow circulation of warm air on both sides of the wall.

TABLE OF PROTECTION PERIODS FOR VARIOUS MORTAR MIXES

Mortar mix by Volume Cement: lime putty: sand	Outside air temperature below	Temperature of masonry should be	Protection period 40°F. or more to be maintained both sides	
			Ordinary Cement	High Early Cement
1:2:9	40°F.	Above 40°F.	4 days	72 hours
1:1:6	"	"	72 hours	48 hours
1:¼:3	"	"	48 hours	24 hours

CONSTRUCTION PRACTICE FOR MASONRY PROTECTION

Temperature Range	Type of Heating	Masonry Protection
Below 40°F. Above 25°F.	Salamanders	Provide wind breaks
Below 25°F. Above 18°F.	Salamanders	Waterproof paper or Canvas cover
Below 18°F. Above 0°F.	Salamanders or steam	Canvas cover
Below 0°F.	Steam	Complete enclosure

PLASTER

Provide heat to dry out plaster when temperatures fall below 40°F. Plaster that has frozen before it has set results in damp, dark-coloured walls of reduced strength. In curing plaster, provide ventilation, in addition to heat, to remove the water.

Open doors and windows to stimulate more rapid evaporation of water from the plaster. In very humid conditions, even at temperatures above freezing, artificial heat or dehumidifiers may be necessary. Thin coats of plaster will dry

more quickly than thick coats. Heating alone will not dry the plaster. Frequent air changes must also be provided to remove the moisture-laden air and replace it with cool air which, when heated, is capable of taking up moisture. During severe winter weather, it is desirable to introduce air for ventilation at some point in the structure removed from the areas which have been plastered. This will prevent the possibility of thermal shock to the plaster during the early stages of its curing. Since, on many small structures, the heating plant is in operation before the plastering is started, it is often found possible to introduce the air required for ventilation purposes directly to the heating unit from the outside.

Once plastering has started in cold weather, the heating system must be kept in continuous operation. Where the regular heating system cannot be used, coke or kerosene portable heating units may be considered. These units however, require careful supervision since, if they are not carefully adjusted, smoke and fumes may stain the plaster, and in any case will constitute a hazard to the health of the workers.

Because of the large amounts of water which must be removed from the palster, there is always a possibility during winter months of damage to timber woodwork and insulation which are subjected to very high humidity conditions existing in the building. During the summer months, natural air drying of the structure provides the optimum operating conditions not only to remove the water from the plaster but also to protect the structure from the effects of high humidity.

STUCCO

Stucco should not be applied at below-freezing temperatures. The information for protecting stucco based on experience is not sufficient to be used as a basis for hard and fast rules. It is suggested, however, that in freezing temperatures, complete enclosure and steam curing of newly applied stucco be provided.

ROOFING

For built-up roofs, wait for fair weather as it is most important that the deck insulation when used, and all other materials are dry. Any dampness under or between layers of roofing will cause built-up roofs to blister.

If it is necessary to apply roll roofing at temperatures below 45°F., warm the roofing before unrolling to avoid cracking. Before applying the roofing cut the rolls into 18- or 24-foot lengths and lay on a flat surface until the roll lies flat without curls or waves. Asphalt roofing becomes brittle at low temperatures and must be handled carefully.

Do not warm or heat asphalt cement directly over a fire. Put unopened can in hot water to warm. Care must be taken when using asphalt emulsions to see that they do not freeze in cold weather.

PAINTING AND DECORATING

Do not apply exterior paint at temperatures below 50°F. Paint applied in cold weather will not dry properly and will lose its durability and resistance to weathering. For winter work it is best to pre-prime outside trim and millwork in a heated and ventilated building and finish the painting in warm weather. Painting of buildings constructed during the winter is best done in the spring, after the cold weather and before the hot weather sets in.

Temperature for interior painting presents no problem if the heating system is operating. Some ventilation is needed to dry paint. Never paint over fresh plaster. This will slow down the curing of the plaster and with some paints the wet plaster will destroy the paint pigments and so ruin the decorating job.

Cold wet weather slows down the drying of joint taping of drywall construction. Heat should be provided for all joint filling and taping work. Sometimes dehumidifiers can be used to advantage.

Wallpaper should not be applied at low temperatures. If heat is not provided freezing and souring of paste can readily occur. If the paste sours it will spoil the paper. Wet conditions inside the house or papering over fresh plaster will also cause paste souring. A tablespoon of carbolic acid to a bucket of paste reportedly will keep paste good for three or four days. If paper will not dry in this time, increase the heat in the building or use a dehumidifier.

MATERIALS USED FOR PROTECTING WINTER WORK

Enclosures should allow circulation of warm air on both sides of the construction.

Housings may be made of wood, canvas, sheetrock, tarred or asphalt treated paper, plywood or other available materials if they are reasonably tight and safe from wind and snow loading. Housings should be as resistant to fire as is practicable.

For concrete and masonry work enclosures should be left in place for the required curing period. At the end of the curing period, artificial heat can be discontinued and the housing removed. This should be done in such a manner that the fall in temperature at any point in the work will not exceed 10°F. in 24 hours.

Portable and temporary shelters made from canvas, waterproof paper, plywood, lumber, insulation board and hardboard are necessities for most cold weather building. Large tents within which the entire building can be erected are coming into fairly common use. With such an arrangement, together with a suitably controlled means of heating the enclosed space, even such operations as exterior painting can be safely carried out.

Temporary enclosures should be well built. Snow and wind loads must be taken into consideration. For large enclosures, plywood, hardboard, or insulated sheathing should cover the framework and canvas or waterproof paper should be placed over the sheathing material. For small areas or small storage enclosures, a well-braced frame covered with canvas or waterproof paper will suffice.

Where scaffolding is used around the walls, it is now common practice to fasten sheet materials to the outside of this to provide a complete enclosure for the work as it progresses. For lighting, some sheets of the enclosing material can be replaced by transparent plastic sheets such as polyethylene. Cases are reported where large sheets of these transparent materials have been used for the entire enclosure over a supporting framework or scaffold.

HEATING EQUIPMENT FOR WINTER WORK

Steam boilers are recognized as an economical source of heat for winter jobs. Depreciation of boilers on large jobs is rated at between 10 to 20 per cent. Pipelines are rated to depreciate from 50 to 70 per cent per season.

On the average job, the capacity of a boiler should be from 2 to 2½ boiler horse power per yard of concrete per hour of maximum demand. Steam from the boilers may be used to:

(1) heat the various buildings used;

(2) heat the concrete aggregates and mixing water;

(3) thaw out forms;

(4) protect the concrete after placement.

For the use of boilers for heating the materials used in making concrete, the following data may be useful:

(1) One boiler h.p. (33.5 thousand B.t.u.'s per hour) will raise the temperature of 30 gallons of water about 100°F. in one hour;

(2) One boiler h.p. will raise the temperature of 1 ton of moist unfrozen aggregate about 60 to 65°F. in one hour;

(3) One boiler h.p. will raise the temperature of about 1 ton of the frozen aggregate about 30 to 40°F. in one hour;

(4) When steam is used for heating aggregates and water, the required boiler capacity per yard of concrete, per hour will range from about 1 h.p. for mild winter weather to about 2½ h.p. for fairly severe winter weather.

For boilers of the type and capacity discussed here, about 140 sq. ft. of steam radiation is equal to 1 boiler h.p.

Steam unit heaters, portable warm-air units equipped with blowers, coal-, coke-, and oil-fired salamanders and gas-burning units are all commonly used in present-day cold-weather work. It is important to note that extreme care should be exercised in the handling and locating of this equipment.

Coke-burning equipment should not be left unattended and enough ventilation of enclosures should be provided to take care of harmful gases that are sometimes given off by such units. Portable coke ovens produce sulphurous acid which produces rust on hardware. Hardware should be coated therefore when these units are used.

Electric heating requires from 25 to 30 kwh. per cubic yard of concrete and is economical when power can be obtained cheaply. Terminal electrodes supplying the heat in the concrete can be iron wire, bars, or stripped sheets. These terminals may be placed on metal form surfaces, the concrete surface, or within the concrete. Branch wires from the switches can be ordinary No. 8 or No. 10 galvanized wire carrying either 220 or 110 volts.

Infra-red rays are being used on some winter concrete jobs. Banks of five 250-watt infra-red lights are used to keep fresh concrete from freezing. These are the ordinary bulbs for therapeutic heat lamps and can be bought in drug, hardware or appliance stores. Job-made troughs fitted with light sockets contain the lamp banks. The troughs are deep enough to protect the lamps and are about 20 feet long. The trough is set horizontally on the working platform and the lamps are directed at the form surfaces. These units have been used successfully for protecting concrete placed at -15°F. It is suggested that the lamps be not placed too close to wood forms or tarpaulins because of the fire hazard involved.

Natural gas, where available, is often used to supply heat for winter construction jobs. Where there is no fire hazard, it is common practice to use open flares; otherwise gas-fired unit heaters are used.

ELECTRIC LIGHTING

Because of the shorter days and cloudy weather associated with the winter months in Canada, artificial illumination must be provided on most construction jobs. It is generally considered that for construction work, a light intensity of 10 foot-candles must be provided for the ordinary construction operations. On small construction jobs this usually involves between 5 and 10 100-watt bulbs per 1000 square feet of area. Where power lines are already installed, no difficulty is experienced in obtaining a temporary power line to the job for the operation of electrical equipment as well as lighting equipment. Portable generators, of which there are a large number on the market, can be used where power lines are not available.

CONCLUSION

This bulletin has attempted to indicate some of the techniques used in Canada by contractors working throughout the winter months. There is little to be found in these pages which will be new to those familiar with winter construction but it is hoped that many contractors who in the past have stopped construction in the late fall, will be encouraged to so plan their construction that it will be possible for them to continue throughout the winter months. It should be pointed out that while many protective measures must be taken during the winter, good control can be maintained of the various jobs associated with construction work. This often results in a superior structure over one built, for example, during extremely hot summer weather when it is very difficult to provide protective measures for concrete and masonry.

For builders who are interested in data on snowfall, wind, and design temperatures in various parts of Canada, a "Climatological Atlas of Canada" has been prepared. Copies of the Atlas (NRC 3151) are available for $2.00 from the National Research Council, Ottawa.

For references to the literature on a wide range of subjects pertaining to winter construction, a listing entitled "A Bibliography on Cold Weather Construction" has been prepared by the Division of Building Research. Copies are available without charge.

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